(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 489 720 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
02.07.1997 Bulletin 1997/27

(51) Int Cl.[6]: **F23D 14/60**, F26B 23/02, F26B 3/30, F26B 13/10

(21) Application number: **92104657.9**

(22) Date of filing: **06.12.1983**

(54) **Method and apparatus for uniformly drying moving webs**

Verfahren und Vorrichtung zum gleichmässigen Trocknen einer laufenden Warenbahn

Méthode et dispositif pour sécher, d'une façon uniforme, une bande en mouvement

(84) Designated Contracting States:
AT BE CH DE FR GB LI LU NL SE

(30) Priority: **10.12.1982 US 448619**

(43) Date of publication of application:
10.06.1992 Bulletin 1992/24

(62) Application number of earlier application in accordance with Art. 76 EPC: **84900238.1**

(73) Proprietor: **KRIEGER CORPORATION**
East Providence Rhode Island 02916 (US)

(72) Inventors:
- **Roth, Reinhold C.**
Newport, Rhode Island, 02840 (US)
- **Terra, Richard C.**
Middletown, Rhode Island, 02840 (US)

(74) Representative: **Thul, Hermann, Dipl.-Phys.**
JAGENBERG AG
Zentrale Patentabtlg.
Kennedydamm 17,
(Rheinmetall-Gebäude)
40476 Düsseldorf (DE)

(56) References cited:
EP-A- 0 062 316
DE-A- 2 251 994
DE-C- 475 075
GB-A- 1 247 891
US-A- 3 214 845
US-A- 4 188 731
CH-A- 125 585
DE-B- 1 011 557
DE-C- 966 023
US-A- 3 091 441
US-A- 3 791 049

Printed by Jouve, 75001 PARIS (FR)

Description

The present invention pertains to drying an elongated web, in particular for the purpose of eliminating wet streaks and/or adjusting the moisture profile in the cross-direction of a moving web of paper or fiber as part of the drying cycle. The invention also relates to controlling the intensity of individual burner elements emitting infra-red radiation for use in said drying operation.

A number of applications exist wherein it is desirable, for example, to selectively apply heat to a moving web, which is subject to drying by other means, for the purpose of eliminating wet streaks or areas of higher moisture concentration and/or to obtain a desired moisture pattern across the web. This process of selectively applying varying amounts of heat across a moving web for the purposes of eliminating and/or adjusting moisture variation across the web will hereinafter be termed "profiling". For practical reasons, the energy density must be high to achieve profiling in drying operations. Therefore, fossil fuel burners or emitters are preferred rather than electric energy. The problem then becomes one of controlling the amount of fuel or the amount of combustible gases delivered to individual burners or emitters in such a manner as to effect profile control in increments corresponding to the moisture variations across the web without turning off the burner or emitter.

For example, in the paper making field, paper is produced in the form of an elongated web, which web is comprised of wood pulp saturated with water. The water is removed from the wood pulp by squeezing the wood pulp as it passes between cooperating rollers and further by drying the web formed by the wood pulp through suitable drying means in order to reduce the moisture content to a value within a controlled range. An instrument for detecting moisture content is typically utilized to monitor moisture content of the moving web. The instrument may be located either upstream relative to and/or following the location of the dryer units. The variation in moisture content across the width of the moving web, i.e., in a direction transverse to the direction of movement of the web (the "cross" direction), frequently presents a serious problem for effectively and efficiently drying the web. To maintain a given moisture range in the final product, the moving web often has to be remoistened and/or overdried, resulting in expensive waste of energy, reduction in machine productivity, increased manufacturing cost and sacrifice of product quality. It is thus extremely desirable to provide apparatus for controlling the web drying operation in a localized manner to obtain the desired moisture range while, at the same time, either eliminating or significantly reducing the above-mentioned disadvantages.

Controling individual burner/emitter elements (E) established in a grid consisting of (m x n) elements, as shown in Fig. 6 where (m) denotes the number of columns and (n) the number of rows in the grid, a minimum of one row but more frequently 4-6 rows are used depending on the amount of water that has to be evaporated in order to achieve a levelled moisture profile. The number of columns required is dependent on the width of the web and the size of the individual elements. For example, in a web 3048 mm (120 inches) wide, 20 elements could be typically used if the elements were 152,4 mm (6 inches) wide.

For illustration purposes, it is simple to examine a small grid consisting of 4 x 5 elements as shown in Fig. 6, providing an arrangement of 5 columns and 4 rows of elements.

Each burner/emitter E has a maximum output of 100% under normal operating conditions. By restricting the fuel flow to the burner, its energy output can be turned down to about 20% without the risk of flame-out. The turn-down ratio is therefore 80%. Let it further be assumed that the 80% turn-down corresponds to a water evaporation load of 4,536 kg (10 lbs)/element/hour. Each column (of 4 emitters) thus has a turn-down capability of 18,144 kg/h (40 lbs)/h and a maximum evaporation rate of 40/0,8 = 22,68 kg/h (50 lbs/h). By varying the number of rows that are turned down, it is possible to change the turn-down of each column to be either 18,144 kg (40 lbs), 13,608 kg (30 lbs), 9,072 kg (20 lbs), or 4,536 kg (10 lbs). 4,536 kg (10 lbs) turn-down for a column would thus be achieved by having 3 rows turned down and 1 row fully on.

This particular illustration gives a total turn-down of 18,144 kg (40 lbs) per column in 4,536 kg (10 lbs) increments. It is also possible to change either the total turn-down by adding or deleting rows to the grid or by decreasing the increment by setting the amount of turn-down to a fraction of the 4,536 kg (10 lbs) per emitter rating. If one, for instance, set the turn-down of row 1 to half of the total turn-down or 2,268 kg (5 lbs), it would be possible to achieve a total column turn-down of 15,876 kg (35 lbs) in 2,268 kg (5 lb) increments as follows:

Row # Turned Down	kg (Pounds) of Turn-Down	
1	2,268	(5)
2	4,536	(10)
1 + 2	6,804	(15)
2 + 3	9,072	(20)
1 + 2 + 3	11,34	(25)
2 + 3 + 4	13,6080	(30)

(continued)

Row # Turned Down	kg (Pounds) of Turn-Down	
1 + 2 + 3 + 4	15,876	(35)

By varying the number of rows used and by selecting the proper turn-down fraction for each row, it is possible to vary the drying intensity to accurately match moisture variations across a moving web which is subject to drying to establish a levelled moisture profile. By changing the size of the elements in the cross web direction (i.e., to greater or less than 152,4 mm (6 inches)), it is also possible to vary the resolution of the drying intensity across the web.

The present invention describes two different modes of altering the fuel flow to each burner/emitter in order to achieve the turn-down of the element.

(a) Mechanically restricting the fuel or the air or the fuel/air mixture.
(b) Pneumatically restricting the fuel or the fuel/air mixture by injecting a counter-current airflow downstream of the fuel orifice to serve as a pressure regulating device or achieve a blocking function through the use of an air curtain.

Either method is characterized by the use of a flow blocking device which operates discretely in two different modes, open - high fire or closed - low fire. This approach makes it possible to use simple three-way solenoid actuators to operate the mechanical restrictor or the pneumatic air curtain or pressure control. The solenoid is fast, reliable and minimizes the number of moving parts and the low fire mode provides repeatability and easy flame monitoring and fast temperature response.

The pneumatic restrictor injects a countercurrent air flow into an air/gas mixing chamber or a manifold located down-stream of the mixing value employed for metering/mixing of combustion gas and air. The back pressure created in the mixing chamber by the countercurrent air flow reduces the combustion air flow through the gas/air orifice of the mixing valve. The mixing valve typically utlilizes a venturi orifice. The venturi action in the orifice, created by the air flowing past the venturi establishes a vacuum which accurately meters the gas drawn into the mixing chamber. The back pressure established by the introduction of the countercurrent air flow through a control inlet, which counter-current air flow is of greater pressure than the pressure of the combustion gas/air mixture in the mixing chamber, reduces the flow of combustion gas passing through the venturi orifice, which in tum meters less gas into the mixing chamber.

By varying the flow of countercurrent of air into the mixing chamber, the intensity of the burner can be varied continuously from high to low fire without the need for shutting off the bumer completely, which would then require automatic reignition and flame monitoring for individual burners. A complete shut-off is disadvantageous since it also increases the heat-up period of the bumer.

The benefits of utilizing a reverse flow obtained through an air jet for changing the burner intensity reside in the ability to achieve continuous ignition and the elimination of unnecessary mechanical parts and in the safety of utilizing an air stream as a means of control. In one preferred embodiment, a solenoid valve can be utilized to control the flow of the air jet for switching between two discrete positions, viz., full fire and low fire. The air pressure of the air supply used to supply the reverse flow air jet is higher than that of the mixing chamber to prevent leakage of combustion gases back into the air supply line of the air jet.

The operation of the solenoids for the countercurrent air jet can be controlled manually to change the flow rate or can be controlled automatically by control means which may include a microprocessor which, in turn, can be interfaced with a scanning moisture measuring device. The latter technique is extremely useful in moisture profiling applications, as will be more fully described.

The countercurrent air flow nozzle may be designed to achieve countercurrent turbulence to directly alter the venturi effect and thereby reduce the ratio of the gas/air mixture. The countercurrent air flows can be utilized in a variety of different mixing chambers and/or gas/air manifolds.

The mechanical restrictor utilizes a pneumatically operated solenoid having a needle valve which is rapidily and selectively driven between a portion which is a predetermined distance into an opening provided in the mixing valve which receives the combustible gas and a position withdrawn from the first position, the movement being responsive to the amount of drying desired. The depth of entry of the needle valve into the opening determines the amount of restriction. The depth may be controlled by placement of washers of different thickness or of a different number of washers of uniform thickness within the piston cylinder to control the entry depth of the needle valve into the mixing valve opening.

Alternatively, the restrictor may comprise a solenoid operated shutter which provides a larger (full flame) or smaller (pilot flame) opening for controlling the air/gas flow and hence the heat intensity of the burner.

A plurality of emitter assemblies may be utilized and control means for selectively operating the sectional units of these assemblies can be provided to accurately control the desired amount of drying (i.e., moisture reduction) by selective operation of each of the individual sectional units making up each assembly to thereby dry elongated sections of the paper web. For example, four such assemblies may be arranged at spaced parallel intervals and transverse to the path of movement of the web. Each assembly is comprised of a pluraltiy of sectional units. Each of the rows of air/gas mixing devices may be preadjusted to reduce moisture content by predetermined fractions of moisture reduction. As one example, the moisture content of the web may be reduced over a range of one-quarter precent to two and three-quarter percent at one-quarter percent increments.

The invention is extremely useful for "profiling". For example, when the moisture content profile across the web indicates that the web has a nonuniform moisture content and/or moisture content which departs significantly from a preferred moisture content, the individual sections of the emitter assemblies may be selectively controlled by the countercurrent air flow provided at the control inlet of each dryer unit section. The independent control of each dryer unit section provides a superior corrective adjustment of localized departures from the target moisture value at a significant reduction in total energy re-quirements.

The control inlet for communicating the air jet with the mixing chamber may be designed to provide an air curtain having a "fishtail" shape for blocking the gas/air flow in addition to regulating the countercurrent flow. Other shapes of air blast may be provided if desired. The air jet velocity may be adjusted to provide either turbulent or laminar flow. The mechanical restrictors may be used in place of the pneumatic restrictors with equal success.

The prior art fails to recognize the problems recognized by the inventor and also fails to teach the novel features of the present invention. More particularly:

German Patent No. 475,075 discloses a mechanically controlled burner for adjusting the amounts of fuel and air, as well as the size of the mixing chamber, as a function of steam pressure developed in a steam boiler being heated by the burner. There is no teaching of regulation of the flame intensity of the burner between a higher and a lower intensity in a substantially instantaneous manner through the introduction of controlled air into the gas/air mixture to regulate the flame intensity.

The published EPO application designated EP-A-0 062 316 discloses a control system for a gas burner in which a movable lance is adjusted to regulate the size of a plurality of openings which introduce air and gas into the burner mixing chamber. There is no teaching of employment of mechanical means which is utilized to rapidly adjust the gas/air mixture between a higher and a lower flame intensity.

Swiss Patent No. 125,585 discloses apparatus for providing an air/gas mixture in which a needle is axially adjusted to regulate the position of its tapered point within an opening by manual rotation of a threaded end portion of the needle, to regulate the air/gas mixture. Again, there is no teaching of substantially instantaneously controlling the burner between a higher and a lower intensity level through mechanical means.

German Published Application No. 2 251 994 discloses air/gas mixing apparatus in which a gas is initially mixed with air in a prechamber wherein the amount of air introduced into the prechamber is a function of gas pressure; and wherein air under pressure is mixed with ambient air in a second prechamber, the amount of ambient air introduced being a function of the pressure of the source of air under pressure, the two mixtures being combined a mixing chamber. Again, there is no teaching of mechanically adjusting the flame intensity between a higher and a lower intensity level in a substantially instantaneous manner.

The document DE-B-1 011 557 discloses manually adjustable means having a handle for manual manipulation for purposes of controlling the air flow, the gas flow being constant.

US-Patent 3,214,845 discloses a methode and means for correcting the moisture profile drying in the manufacture of fibrous materials in which one drying section with a series of selective drying means is spaced across the material. The variations in moisture across the width of the material are determined, and in accordance with the measured moisture content the output of each of the selective drying means is adjusted.

US-A-4 188 731 and DE-C-966 023 disclose radiant heating elements being positioned in a grid system adjacent a moving web, the heating elements being controlled either individually or in groups to be either in an in-position or in an off-position.

Although it is conventional to measure moisture across a web, there is no teaching of the profiling technique disclosed herein wherein columns of emitters are selectively operated between upper and lower flame intensities to regulate moisture content in the cross-direction of a web to achieve a desired moisture profile.

It is an object of the present invention is to provide a novel apparatus for drying moving webs and the like comprised of a plurality of drying units and which are adjustable preferably between first and second energy levels for controlling each infrared emitter unit to regulate the adjustment of the moisture level.

Still another object of the present invention is to provide a novel method for regulating the moisture profile of a web in which the heat intensity of the drying units, arranged in a predetermined number of rows, each drying unit having a number of independently controllable emitter units extending in the cross-direction of the web wherein the percent of drying is regulated by selectively controlling the drying energy of elements in like columns of the rows of drying units

to obtain incremental drying levels ranging between a maximum and a minimum drying level by selectively adjusting the air/gas mixture of each element in a like column to obtain flame intensities at a variety of graduations between an upper and a lower drying level.

Still another object of the present invention is to provide a novel method for regulating the moisture profile of a web in which the heat intensity of the drying units, arranged in a predetermined number of rows, each drying unit having a number of emitter units extending in the cross-direction of the web wherein the percent of drying is regulated by controlling the intensity of elements in like columns of the rows of drying units to obtain incremental drying levels ranging between a maximum and a minimum drying level by selectively adjusting the air/gas mixture of each element in a like column to obtain flame intensities between an upper and a lower level and wherein the adjustments are made under the control of a moisture detection apparatus which is operated to determine the moisture profile across the web to appropriately regulate the individual drying elements within each drying unit.

The invention is defined in claims 1 and 4, optional features being set out in the dependent claims.

The invention will become apparent when reading the accompanying description of drawings in which:

Fig. 1	shows a portion of a dryer unit embodying the principles of the present invention.
Fig. 2	shows a simplified perspective view of a system employing a plurality of drying units embodying the principles of the present invention.
Fig. 2a	is a perspective view showing one of the dryer units of Fig. 2 in greater detail.
Figs. 3a and 3b	show side and end views respectively of another type of dryer unit utilizing the principles of the present invention.
Figs. 4a and 4b	show elevational and top views, respectively, of another preferred embodiment of the present invention.
Figs. 5a and 5c	respectively show diagrams of the heating system before profiling and with profiling responsive to a given moisture profile.
Figs. 5b and 5d	respectively show a moisture profile across a web before profiling and after profiling.
Fig. 6	shows a diagram of another simplified profiling system useful in understanding the present invention.
Fig. 7	shows a sectional view of another alternative embodiment of an infra-red burner for use in the profiling system of the present invention.
Fig. 7a	shows a detailed view of the mixing valve and mixing chamber of the burner units shown in Fig. 7.
Fig. 7b	is a sectional view of an alternative embodiment for the mixing valve shown in Fig. 7a.

Fig. 1 shows a portion of a drying unit 10 embodying the principles of the present invention and comprised of a gas supply manifold 12 receiving a combustion gas from a combustion gas supply source (not shown) and for delivering the combustion gas through manifold 12 and coupling 14 to a hollow conduit 16 which may, for example, be a U-shaped tube having an arm 16a and an arm 16b, the yoke portion of the conduit 16 being omitted from Fig. 1 for purposes of simplicity. Conduit portion 16b delivers the combustion gas through coupling 18 to an L-shaped coupling 20 for introducing the combustion gas into the venturi orifice 22a of a venturi-type mixing valve 22. Mixing valve 22 is air-tightly fitted within the upper opening provided in mixing chamber 24. Mixing valve 22 is provided with a tapered intermediate portion 22c which tapers from a large diameter portion 22b to a small diameter portion 22d. The free end of small diameter portion 22d is tapered at 22e. A cylindrical disk 26 is provided with diagonally aligned openings 26a (see Fig. 7a) surrounding tapered portion 22e. A portion of the hollow region between mixing valve 22 and mixing chamber 24 is arranged to receive air introduced through an opening 24a in mixing chamber 24 and an opening 28a in an air supply manifold 28 for delivering air under pressure to the mixing chamber. Air under pressure is introduced through openings 28a and 24a and flows about the exterior portion of mixing valve 22 and downwardly into the hollow interior of mixing chamber 24, as shown by arrows 30. The air passing the venturi orifice 22a creates a vacuum condition which draws combustion gas through the orifice and into the mixing chamber 24 in a controlled and measured amount. The gas/air mixture continues to move downwardly and into a combustion chamber 32, passing through an opening 34a in a

member 34 and through a plurality of hollow, cylindrically-shaped elements 36 to enter into the combustion chamber 32. The elements 36 are arranged within a wall formed of a suitable insulation material to provide a plurality of orifices for introducing the air/gas mixture into the combustion chamber.

A spark ignitor 38 is arranged within hollow, cylindrical member 40, the centrally located electrode 38a extending into combustion chamber 32 to develop a spark for igniting the air/gas mixture within combustion chamber 32. Burning takes place in chamber 32 in order to heat the substantially U-shaped radiating elements 40. The combusted air/gas mixture heats elements 40 causing them to emit heat radiation in the infra-red range. Burning is sustained by continuous flow of the air/gas mixture into the combustion chamber 32.

The infrared emitter unit 42 is positioned above a moving web W which web is moving, for example, in a direction out of and perpendicular to the plane of Fig. 1. Units 42' and 42" are substantially identical to the infra-red emitter unit 42, and are arranged in an end-to-end manner. The emitter units 42' and 42" are joined to unit 42 by pins 46 extending through openings in the walls 48, 50 of unit 42, as well as the walls 48', 50' and 48", 50" of the infra-red emitter units 42' and 42", respectively.

In order to regulate the flow of the air/gas mixture which is delivered to combustion chamber 32 through the mixing chamber 24, chamber 24 is provided with a control inlet 52, preferably in the form of a hollow externally threaded member, for coupling a second air supply 54 therethrough, preferably through an adjustable valve 56 and a solenoid controlled valve 58.

The air pressure developed by source 54 is substantially greater than the pressure within air/gas mixing chamber 24 to prevent the passage of the air/gas mixture through inlet 52 and back to source 54.

Adjustable valve 56 may be adjusted to regulate the flow of air from source 54. Solenoid control valve 58, in one preferred embodiment of the invention, is comprised of a solenoid operated, two position valve assembly, having a first position which is normally closed to prevent the passage of air from source 54 into control inlet 52 and likewise to prevent the air/gas mixture in mixing chamber 24 from passing through inlet 52 and toward source 54.

By energizing the solenoid of the solenoid control valve assembly 58, the valve is moved to the open position to allow a jet of air from source 54 to pass through adjustable valve 56, open solenoid valve 58 and inlet 52 into mixing chamber 24.

The introduction of a jet of air into mixing chamber 24 through control inlet 52 develops a back pressure condition resulting from the countercurrent air flow of greater pressure than that of the combustion gas/air mixture to reduce the venturi effect and thereby causing the gas/air mixing valve 22 to meter less gas through orifice 22a and into mixing chamber 24. The reduction in the proportions of air and gas in the air/gas mixture due to the back pressure developed in mixing chamber 24 reduces the burning and heating level within combustion chamber 32 to thereby reduce the intensity of infra-red radiation emitted from the radiating surfaces 40, the amount of reduction in heat intensity being a function of the pressure level of air pressure source 54 and the adjustment of adjustable valve 56.

Care must be exercised in the selection of the size of inlet opening 52. If the opening is too small, the velocity of air jet moving through inlet 52 will be too great. This will create a vacuum effect causing more, rather than less, gas to be drawn into the mixing chamber through the venturi. It appears that turbulent air flow creates the undesirable vacuum condition whereas lamilar air flow blocks the flow of the air/gas mixture in the region of the countercurrent air jet.

The moving web, which may be paper, cloth or any other material, is preferably monitored by a moisture level detection instrument 102 having a moisture detecting head 126 electrically connected thereto. The moisture detector apparatus may, for example, be of the type described in U.S. Patent No. 3,458,808 issued 29 July 1969 or U.S. Patent No. 3,829,754 issued 13 August 1974 as exemplary of satisfactory moisture detection devices which utilize microwave detection cavities. However, any other type of moisture detection device may be utilized including manual observation. A moisture level is thus detected and, if this moisture level is not within a desired moisture level range, control logic 128 coupled to the moisture detector head 126 is utilized to close solenoid 58 to provide radiation intensity at a level sufficient to reduce the moisture content of the web to an acceptable level. In the event that the moisture level content lies below the desired range, the moisture detector unit 102 develops a signal which opens normally closed solenoid 58 to significantly reduce the intensity (drying) level since the web is below the desirable moisture content level. The lower intensity level is preferably sufficient to provide only minimal drying while avoiding the need for reignition of the air/gas mixture, resulting in a saving of both electrical energy and combustion gas.

The detector head 126 (see Fig. 2) may be comprised of a plurality of independent detector heads, each capable of measuring moisture content over a portion of the width of web W.

Alternatively, a single scanning head may be employed. The single scanning head may be comprised of only one detector head 126 which scans across the width of the web. A moisture reading is taken at discrete intervals of the scan (i.e., movement) of the single detector head across the web.

As one example of moisture level control, let it be assumed that the desired average moisture content across web W should be of the order of six percent. Considering Fig. 2a, let it further be assumed that the portions W_1, W_3 and W_5 of the web W have a moisture content of the order of six percent; that the portion W_2 of the web W has a moisture content of the order of five percent and that a portion W_4 of the web has a moisture content of the order of nine percent.

The average of these moisture contents exceeds six percent, which is the desired average. By utilizing a dryer unit having infrared emitter units whose air/gas mixtures are adjusted to reducing the moisture content in the associated section of the web by two percent, the moisture content can locally be reduced in section W_4 sufficiently to bring the average moisture content across the web below the desired six percent average value. This may, for example, be accomplished through the use of a dryer unit having infrared emitter units 42 whose combustion gas/air mixtures are each adjusted to provide a marginal reduction in moisture content when the solenoid valve 58 is opened to reduce the intensity of the flame. Each infrared emitter unit 42 is further capable of being operated to provide a two percent reduction in moisture content by closing the solenoid valve 58 to thereby increase the flame intensity. The heat intensity (i.e. drying level) is further adjustable by controlling the pressure level of the air pressure source 54 and further by controlling the adjustment of regulating valve 56 (either manually or automatically), as shown in Fig. 1. Thus, the moisture profile is thus readjusted to an acceptable profile at a significant saving in energy consumption, while at the same time preventing portions of the web from being overdried.

The arrangement 100 of Fig. 2 employs a plurality of dryer units 106, 108, 110 and 112, arranged in spaced parallel fashion and extending transversely across moving web W. The drying units 106 through 112 are each comprised of a plurality of infrared emitter units 42 which may be of the infra-red emitter type 42 shown in Fig. 1, or may be any other suitable type of dryer heated by an air/gas mixture. The size of each infrared emitter unit in the cross direction of the web is preferably small, such as 6" or so, to improve monitoring resolution in the cross direction of the web. Fig. 2 shows the drying units in simplified diagrammatic fashion. Fig. 2a shows one typical unit 106 comprised of infrared emitter units 42 each having a mixing chamber 24 receiving air (for combustion) from air source 114 through line 116 and receiving gas from gas source 118 through line 120. Each control inlet 52 receives air under pressure (for control) from air source 122 through line 124. Valves 58 are electrically controlled by signals from control unit 130 which receives moisture content signals from the signal output portion 128 of scanning head 126 or from a manual input. The drying units 108-112 are substantially identical to unit 106.

The electronic control unit 103 operating solenoid control valves may incorporate a microprocessor.

The operation of the dryer system in Fig. 2 is as follows:

Figs. 5a-5d illustrate the use of the profilng system on a typical paper machine operating to move the web W in the speed range of 1200-1800 fpm. In the example shown in Figs. 5a-5d, the system consists of 4 rows of burner units 106-112, each unit being comprised of infrared emitter units 42, measuring 4" x 6" in size. Each infrared emitter unit 42 can be individually controlled to a high or low heat intensity. The difference between the two levels is the "turndown". Rows 1-3 have been set to yield a turndown (reduction) of 1% final moisture, whereas Row 4 has a turndown of 1/2% to allow the moisture control in 1/2% increments. The total turndown for this illustration is therefore 3-1/2%. This means a correction capability of +2%; -1-1/2% around a desired moisture target.

The dryer system 100 is initialized with 50% of its capacity turned on (See Fig. 5a). The moisture profile at the reel (i.e., where the paper web is wound up) measured by scanning head 126 shows a tyical profile variation (see Fig. 5b) which requires a moisture target of 4% in order not to exeed a maximum of 6%. Each rectangle in Figs. 5a and 5c represents an infrared emitter unit 42. A shaded rectangle represents a section which is "ON" (i.e., high heat) while an unshaded rectangle represents a section which is "OFF" (i.e., low or marginal heat).

The infrared emitter units 42 of the dryer system 100 are readjusted as shown in Fig. 5c to provide differential drying based on the moisture content profile shown in Fig. 5b either as measured by the scanning moisture head or as determined by an operator. The resulting final profile is shown in Fig. 5d as being tightly clustered around the original moisture target of 4%.

The paper web can then be run faster or the amount of steam consumed in the paper making process can be reduced to increase the final moisture target from 4% to 5-1/2% resulting in substantial steam and fiber savings and allow a machine speed-up. This technique of providing localized corrections in the moisture profile also results in a significant reduction in fuel (i.e., gas) consumption.

Obviously, any other adjustments may be made to provide the desired incremental reduction in moisture content and/or a greater or lesser number of drying units may be provided depending upon the needs of the particular application. Some other examples are given in the following chart:

OTHER TYPICAL REDUCTIONS				
Increments Burner Units	1/4%	1/3%	1/2%	1%
1	1/4	1/3	1/2	1
2	1/2	2/3	1	1
3	1	1	1	1
4	1	1	1	1
Total:	2.3/4%	3%	3-1/2%	4%

Figs. 3a and 3b show another alternative arrangement wherein an assembly 150 is comprised of a plurality of individual heating units 152-l through 152-n, each unit incorporating an elongated burner head 154 (shown in Fig. 3b) for heating a suitable refractory 156, 158 which provides a high rate of radiant heat transfer. Each unit receives an air/gas mixture which is introduced into the inlet end 160a of manifold 160 and is delivered to each unit through the branch conduits 162-l through 162-n. Each branch conduit 162 is provided with a control inlet 164-l through 164-n for introducing air from the supply source such as, for example, the supply source shown in Fig. 1, into each branch conduit in order to provide a back pressure. The coupling connected to one of the conduits 162 may be shaped in the manner shown in Figs. 4a, 4b in order to create a "fishtail" shape air curtain within conduit 162. Noting Fig. 4a, an air supply conduit 166 is provided with a narrowing exit portion 166a which narrowing exit portion flares outwardly as defined by the sidewalls 166b, 166c (shown in Fig. 4b) and the triangular shaped walls 166e, 166d (shown in Fig. 4a). This outlet communicates with an arcuate shaped opening 162a in conduit 162 to cause a narrow "fishtail" shape air curtain to be introduced within the interior of conduit 162 (see Fig. 4b) for blocking the gas/air flow in addition to regulating the countercurrent flow, i.e., the back pressure condition created in the region of the venturi orifice.

Figs. 7 and 7a show an alternative arrangement for regulating the air/gas mixture wherein like elements are designed by like numerals, as compared with Figs. 1 and 7. The unit 200 comprises mixing valve 22 provided with central opening 22a, which selectively receives the reciprocating needle member 212 of a pneumatically driven assembly 210 comprised of housing 214 with an air inlet opening 214a for receiving air under pressure. Needle member 212 is joined to piston 216 arranged within cylinder 214. A return spring 218 is arranged between piston 216 in the bottom end 214b of cylinder 214. Return spring 218 normally urges piston 216 upwardly in the direction shown by arrow 220. Gas enters into a closure cap 222 having a gas inlet opening 222a and passes through an annular path described by needle 212 and central opening 22a. When no air under pressure is applied to the control inlet opening 214a, return spring 218 urges piston 216 and needle 212 upwardly, allowing unrestricted (maximum) gas flow to provide a rich gas/air mixture in mixing chamber 24. Application of air under pressure to control inlet opening 214a urges piston 216 and needle 212 downwardly to extend more deeply into central opening 22a and the reduced diameter portion 22a' thereof, thereby reducing the amount of gas entering into mixing chamber 24 and providing a leaner gas/air mixture which reduces the energy output of the burner. However, a sufficient amount of gas is preferably introduced into the mixing chamber to sustain combustion and thereby avoid the necessity of initiating a new start-up. The depth of entry of needle 212 into mixing valve opening 22a may be controlled by placing washers W within cylinder 214 or between cylinder housing 214 and the top of closure cap 222, or by adjusting the height of cylinder housing 214 relative to closure cap 222, thus limiting the depth of penetration of the needle 212 into opening 22a. The washers may either be of varying thickness or may be of one uniform thickness with the number of washers introduced controlling he overall depth reduction. The arrangement shown in Figs. 7 and 7a may be utilized with equal success in any of the dryer units described hereinabove and as a substitute for the countercurrent gas flow control means shown, for example, in Figs. 1, 2, 3 and 4. The air introduced into cylinder inlet 214a may be regulated by a solenoid controlled valve 215.

Instead of applying needle member 212 to the flow of gas alone as shown in the above arrangement, an alternate arrangement as shown in Fig. 7b employs a needle member 212' of extended length to also control the flow of combustion air 30 or to regulate a mixture of gas and air as shown in arrangement 150 of Figs. 3a and 3b by replacing the air flow device by a mechanical needle device of the type shown in Fig. 7b.

An additional variation may employ a solenoid blocking valve directly on the mixing tube (162) or (24), such blocking valve having an orifice opening in the blocking diaphram to allow passage of a lesser amount of combustible gas in the blocked or closed position. The blocking valve may be in the form of a shutter movable to a first position to provide a large opening (full flame) and a second position to provide a restricted opening (pilot flame).

Since water layers of the type considered in this application have their maximum infra-red absorption in the wavelength region of 1.9 to 1.95 microns, it is highly advantageous to control the infra-red emitters to operate in this portion of the infra-red spectrum to the greatest extent possible. The present invention capitalizes on this phenomenon, since only some (but not all) of the emitters E in a column (see Fig. 6) are turned down while the remaining emitters of the column are operated at high fire, corresponding to the optimum wavelength. An alternative way to make intensity adjustments to a column having one long emitter would be to adjust the intensity of the entire column by conventional means, i.e., butterfly valves. As an example, a 50% turndown of a column would mean that, using the grid approach of the present invention, two out of four emitters E in a column would be in a low fire, whereas the burners of the remaining emitter would be operating at high fire, thus operating at their highest efficiency. A conventional control system would turn down a column emitter to a 50% level, moving the emitters out of the preferred wavelength range, which results in enormous fuel inefficiency.

Although the present invention is described as being extremely useful for heater and dryer units, and for heater and dryer units of the infra-red type, it should be understood that the present invention may be utilized in any application wherein it is desired to alter an air/gas mixture automatically and without either having to shut-off the burner completely or, alternatively, without having to readjust the controls utilized with the lines coupling the combustion gas and air supply sources to the mixing valve and mixing chamber.

A latitude of modification, change and substitution is intended in the foregoing disclosure, and in some instances, some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

Claims

1. Apparatus for drying an elongated web (W) comprising:

   - a plurality of infrared emitter units (42) each for drying a longitudinal portion of the web (W) passing adjacent to said infrared emitter unit (42),
   - said infrared emitter units (42) being arranged in side-by-side fashion to form a drying unit (106, 108, 110, 112),
   - utilizing at least two of the drying units (106, 108, 110, 112) being arranged in spaced parallel fashion,
   - control means for each of the infrared emitter units (42) for selectively operating each infrared emitter unit (42) at a first high energy level and a second level significantly less than said high energy level,
   - means for measuring the moisture content of the web (W) to determine the moisture profile across the web (W),
   - means responsive to the moisture profile and to a desired moisture content for selectively operating the infrared emitter units (42) associated with a given longitudinal section of the moving web (W) between a first extreme condition wherein all of the infrared emitter units (42) for drying a common longitudinal section of the web (W) are operating at said second level and the opposite extreme wherein all of said infrared emitter units (42) associated with the longitudinal section of the moving web (W) are operating at said first level.

2. Apparatus according to claim 1, characterized by a infrared emitter unit (42), comprising:
   a combustion chamber (32) and an apparatus for regulating an air/gas mixture delivered to said combustion chamber (32), a mixing device (22) having a central opening (22a) for receiving gas, a second inlet (22c) for receiving the air, a control member (212) positioned in the opening (22a) of said mixing device (22), whereby the proportionate amounts of gas and air reaching said mixing chamber first inlet is determined by the position of said control member (212).

3. Apparatus according to claim 1, characterized by a infrared emitter unit (42) comprising a combustion chamber (32) and an apparatus for regulating an air/gas mixture delivered to said combustion chamber (32) comprising a conduit (24) having a first inlet for receiving air and a combustible gas and an outlet (34a), said conduit (24) delivering an air/gas mixture to said outlet (34a), said outlet (34a) communicating with said combustion chamber (32), the said apparatus for regulating the air/gas mixture further comprising a mixing device (22) having a first inlet (22a) for receiving gas, a second inlet (22c) for receiving air and a mixing region (26) for mixing said air and gas and delivering the mixture to the conduit first inlet, a control member (212) mounted within said conduit and means (214, 214a, 216) for moving said control member to a first position to provide a large opening for passage of gas therethrough and to a second position to provide a restricted opening for passage of gas therethrough.

4. A method for optaining a moisture profile across a paper web (W) moving through a drying region within a desired moisture range, comprising the steps of:

   - providing a plurality of infrared emitter units (42) each arranged side-by-side spanning across the width of the web (W) to form a drying unit (106, 108, 110, 112),
   - providing at least two of the drying units (106, 108, 110, 112) being arranged in spaced parallel fashion,
   - measuring the moisture content across the web (W) to provide a moisture profile (126),
   - selectively operating all of those infrared emitter units (42) associated with a common longitudinal section of the web (W) whose moisture profile is above the desired range at an output energy level suitable to reduce the moisture level to achieve the desired moisture level.

5. A method according to claim 3, comprising the step:

   - selectively operating those infrared emitter units (42) adapted to dry a common longitudinal section of the web (W) whereby at least one of the said infrared emitter units (42) is operated at a higher output energy level whenever the portion of the moisture profile representative of the moisture content of the associated longitudinal section of the web (W) is greater than the desired moisture level, the number of such infrared emitter units (42) being operated at a higher output energy level being directly proportional to the magnitude of the

difference between the actual moisture level and the desired moisture level.

Patentansprüche

1. Vorrichtung zum Trocknen einer länglichen Warenbahn (W), bestehend aus folgendem:

   - einer Mehrzahl von Infrarotstrahlereinheiten (42), jede zum Trocknen eines Längsabschnitts der Warenbahn (W), die unmittelbar neben der Infrarotstrahlereinheit (42) vorbeiläuft;
   - den Infrarotstrahlereinheiten (42), die Seite an Seite angeordnet sind, so daß sie eine Trocknungseinheit bilden (106, 108, 110, 112);
   - Einsatz von mindestens zwei der Trocknungseinheiten (106, 108, 110, 112), die parallel beabstandet angeordnet sind;
   - Steuerungsmitteln für jede der Infrarotstrahlereinheiten (42) zum gezielten Betrieb jeder Infrarotstrahlereinheit (42) auf einer ersten Hochenergiestufe und einer zweiten Stufe, die wesentlich niedriger ist als die Hochenergiestufe;
   - Mitteln zum Messen des Feuchtigkeitsgehalts der Warenbahn (W) zur Ermittlung des Feuchtigkeitsprofils über die Warenbahn (W) hinweg;
   - Mitteln, welche auf das Feuchtigkeitsprofil sowie auf einen gewünschten Feuchtigkeitsgehalt reagieren, um die Infrarotstrahlereinheiten (42), die einem gegebenen Längsschnitt der laufenden Warenbahn (W) zugeordnet sind, gezielt zwischen einem ersten Extremzustand, in dem sämtliche Infrarotstrahlereinheiten (42) zum Trocknen eines gemeinsamen Längsschnittes der Warenbahn (W) auf der genannten zweiten Stufe betrieben werden, und dem entgegengesetzten Extremzustand, in dem sämtliche der genannten Infrarotstrahlereinheiten (42), die zum Längsschnitt der laufenden Warenbahn (W) gehören, auf der genannten ersten Stufe betrieben werden, zu betreiben.

2. Vorrichtung gemäß Anspruch 1, gekennzeichnet durch eine Infrarotstrahlereinheit (42) bestehend aus: einer Verbrennungskammer (32) und einer Vorrichtung zum Regulieren eines Luft/Gas-Gemischs, das an die genannte Verbrennungskammer (32) herangeführt wird; einer Mischvorrichtung (22) mit einer zentralen Öffnung (22a) für die Aufnahme von Gas; einem zweiten Einlaß (22c) für die Aufnahme der Luft; einem Steuerungsglied (212), das in der Öffnung (22a) der genannten Mischvorrichtung (22) positioniert ist, wodurch die entsprechenden Mengen an Gas und Luft, die die erste Einlaßöffnung der genannten Mischkammer erreichen, durch die Stellung des genannten Steuerungsglieds (212) bestimmt werden.

3. Vorrichtung gemäß Anspruch 1, gekennzeichnet durch eine Infrarotstrahlereinheit (42), bestehend aus einer Verbrennungskammer (32) und einer Vorrichtung zur Regulierung eines Luft/Gas-Gemischs, das an die genannte Verbrennungskammer (32) geführt wird, welche eine Leitung (24) einschließt, die über einen ersten Einlaß für die Aufnahme von Luft und von einem brennbaren Gas und über einen Auslaß (34a) verfügt, wobei die genannte Leitung (24) ein Luft/Gas-Gemisch an den genannten Auslaß (34a) führt und der genannte Auslaß (34a) mit der genannten Verbrennungskammer (32) verbunden ist; wobei die besagte Vorrichtung zum Regulieren des Luft/Gas-Gemischs des weiteren eine Mischvorrichtung (22) mit einem ersten Einlaß (22a) zur Aufnahme von Gas, einem zweiten Einlaß (22c) für die Aufnahme von Luft und einem Mischbereich (26) für das Mischen der Luft und des Gases und für die Zuführung der Mischung an den ersten Einlaß der Leitung, ein Steuerungsglied (212), das innerhalb der genannten Leitung montiert ist, sowie Mittel (214, 214a, 216) für die Bewegung des genannten Steuerungsgliedes in eine erste Stellung, um eine große Öffnung für den Durchfluß von Gas durch dieselbe bereitzustellen, und in eine zweite Stellung, um eine eingeschränkte Öffnung für den Durchfluß von Gas durch dieselbe bereitzustellen, enthält.

4. Verfahren zur Erlangung eines Feuchtigkeitsprofils über eine Papierbahn (W) hinweg, die sich durch eine Trocknungsregion innerhalb eines gewünschten Feuchtigkeitsbereichs hindurchbewegt, mit folgenden Schritten:

   - Bereitstellung einer Mehrzahl von Infrarotstrahlereinheiten (42), die jeweils Seite an Seite angeordnet sind und sich über die Breite der Warenbahn (W) erstrecken, um so eine Trocknungseinheit (106, 108, 110, 112)

zu bilden;

- Bereitstellung von mindestens zwei der Trocknungseinheiten (106, 108, 110, 112), die in parallel und beabstandet angeordnet sind;
- Messung des Feuchtigkeitsgehalts über die Warenbahn (W) hinweg, um ein Feuchtigkeitsprofil (126) bereitzustellen;
- gezieltes Betreiben von all jenen Infrarotstrahlereinheiten (42), die zu einem gemeinsamen Längsschnitt der Warenbahn (W) gehören und deren Feuchtigkeitsprofil sich bei einem Energieabgabewert, der geeignet ist, den Feuchtigkeitsgehalt zu reduzieren, um den gewünschten Feuchtigkeitsgehalt zu erzielen, oberhalb des gewünschten Bereichs befindet.

5. Verfahren gemäß Anspruch 3 mit folgendem Schritt:

- gezieltes Betreiben dieser Infrarotstrahlereinheiten (42), die ausgelegt sind, einen gemeinsamen Längsabschnitt der Warenbahn (W) zu trocknen, wodurch mindestens eine der genannten Infrarotstrahlereinheiten (42) immer dann mit einem höheren Energieabgabewert betrieben wird, wenn der Anteil des Feuchtigkeitsprofils, das für den Feuchtigkeitsgehalt des dazugehörigen Längsabschnitts der Warenbahn (W) repräsentativ ist, höher ist als der gewünschte Feuchtigkeitsgehalt, wobei die Anzahl derartiger Infrarotstrahlereinheiten (42), die mit einem höheren Energieabgabewert betrieben werden, direkt proportional zur Größe des Unterschieds zwischen dem tatsächlichen Feuchtigkeitsgehalt und dem gewünschten Feuchtigkeitsgehalt ist.

Revendications

1. Appareil pour sécher une bande allongée (W) comprenant :

- une pluralité d'unités d'émetteur infrarouge (42), chacune pour sécher une portion longitudinale de la bande (W) passant à côté de ladite unité d'émetteur infrarouge (42),
- lesdites unités d'émetteur infrarouge (42) étant agencées en juxtaposition pour former une unité de séchage (106, 108, 110, 112),
- l'utilisation d'au moins deux des unités de séchage (106, 108, 110, 112) agencées de manière espacée parallèle,
- un moyen de commande pour chacune des unités d'émetteur infrarouge (42) pour activer sélectivement chaque unité d'émetteur infrarouge (42) à un premier niveau d'énergie élevé et à un second niveau considérablement inférieur audit niveau d'énergie élevé,
- un moyen de mesure de la teneur en eau de la bande (W) pour déterminer le profil d'humidité en travers de la bande (W),
- un moyen réagissant au profil d'humidité et à une teneur en eau souhaitée pour activer de manière sélective les unités d'émetteur infrarouge (42) associées à une section longitudinale donnée de la bande en mouvement (W) entre un premier état extrême dans lequel toutes les unités d'émetteur infrarouge (42) pour sécher une section longitudinale commune de la bande (W) fonctionnent audit deuxième niveau et l'extrême opposé dans lequel toutes lesdites unités d'émetteur infrarouge (42) associées à la section longitudinale de la bande en mouvement (W) fonctionnent audit premier niveau.

2. Appareil selon la revendication 1, caractérisé par une unité d'émetteur infrarouge (42), comprenant :
une chambre de combustion (32) et un appareil pour réguler un mélange air/gaz fourni à ladite chambre de combustion (32), un dispositif de mélange (22) ayant une ouverture centrale (22a) pour recevoir du gaz, une deuxième entrée (22c) pour recevoir l'air, un organe de commande (212) positionné dans l'ouverture (22a) dudit dispositif de mélange (22), les quantités proportionnées de gaz et d'air atteignant ladite première entrée de la chambre de mélange étant déterminées par la position dudit organe de commande (212).

3. Appareil selon la revendication 1, caractérisé par une unité d'émetteur infrarouge (42) comprenant une chambre de combustion (32) et un appareil pour réguler un mélange air/gaz fournir à ladite chambre de combustion (32) comprenant un conduit (24) ayant une première entrée pour recevoir de l'air et un gaz combustible, et une sortie (34a), ledit conduit (24) fournissant un mélange air/gaz à ladite sortie (34a), ladite sortie (34a) communiquant avec ladite chambre de combustion (32), ledit appareil pour réguler le mélange air/gaz comprenant en outre un dispositif

de mélange (22) ayant une première entrée (22a) pour recevoir du gaz, une deuxième entrée (22c) pour recevoir de l'air et une région de mélange (26) pour mélanger ledit air et ledit gaz et fournir le mélange à la première entrée du conduit, un organe de commande (212) monté à l'intérieur dudit conduit et des moyens (214, 214a, 216) pour déplacer ledit organe de commande dans une première position pour fournir une grande ouverture permettant le passage de gaz à travers elle et dans une deuxième position pour foumir une ouverture restreinte pour le passage de gaz à travers elle.

4. Méthode pour obtenir un profil d'humidité en travers d'une bande de papier (W) se déplaçant à travers une région de séchage à l'intérieur d'une plage d'humidité souhaitée, comprenant les étapes consistant à :

- foumir une pluralité d'unités d'émetteur infrarouge (42) chacune agencée en juxtaposition transversalement sur toute la largeur de la bande (W) pour former une unité de séchage (106, 108, 110, 112),
- foumir au moins deux des unités de séchage (106, 108, 110, 112) agencées de manière espacée parallèle,
- mesurer la teneur en eau en travers de la bande (W) pour fournir un profil d'humidité (126),
- activer de manière sélective toutes les unités d'émetteur infrarouge (42) qui sont associées à une section longitudinale commune de la bande (W) dont le profil d'humidité est au-dessus de la plage souhaitée à un niveau d'énergie approprié pour réduire le niveau d'humidité pour obtenir le niveau d'humidité souhaité.

5. Méthode selon la revendication 3, comprenant l'étape consistant à :

- activer de manière sélective les unités d'émetteur infrarouge (42) qui sont adaptées pour sécher une section longitudinale commune de la bande (W), au moins l'une desdites unités d'émetteur infrarouge (42) étant activée à un niveau d'énergie plus élevé à chaque fois que la portion du profil d'humidité représentative de la teneur en eau de la section longitudinale associée de la bande (W) est supérieure au niveau d'humidité souhaité, le nombre de telles unités d'émetteur infrarouge (42) actionnées à un niveau d'énergie plus élevé étant directement proportionnel à l'amplitude de la différence entre le niveau d'humidité réel et le niveau d'humidité souhaité.

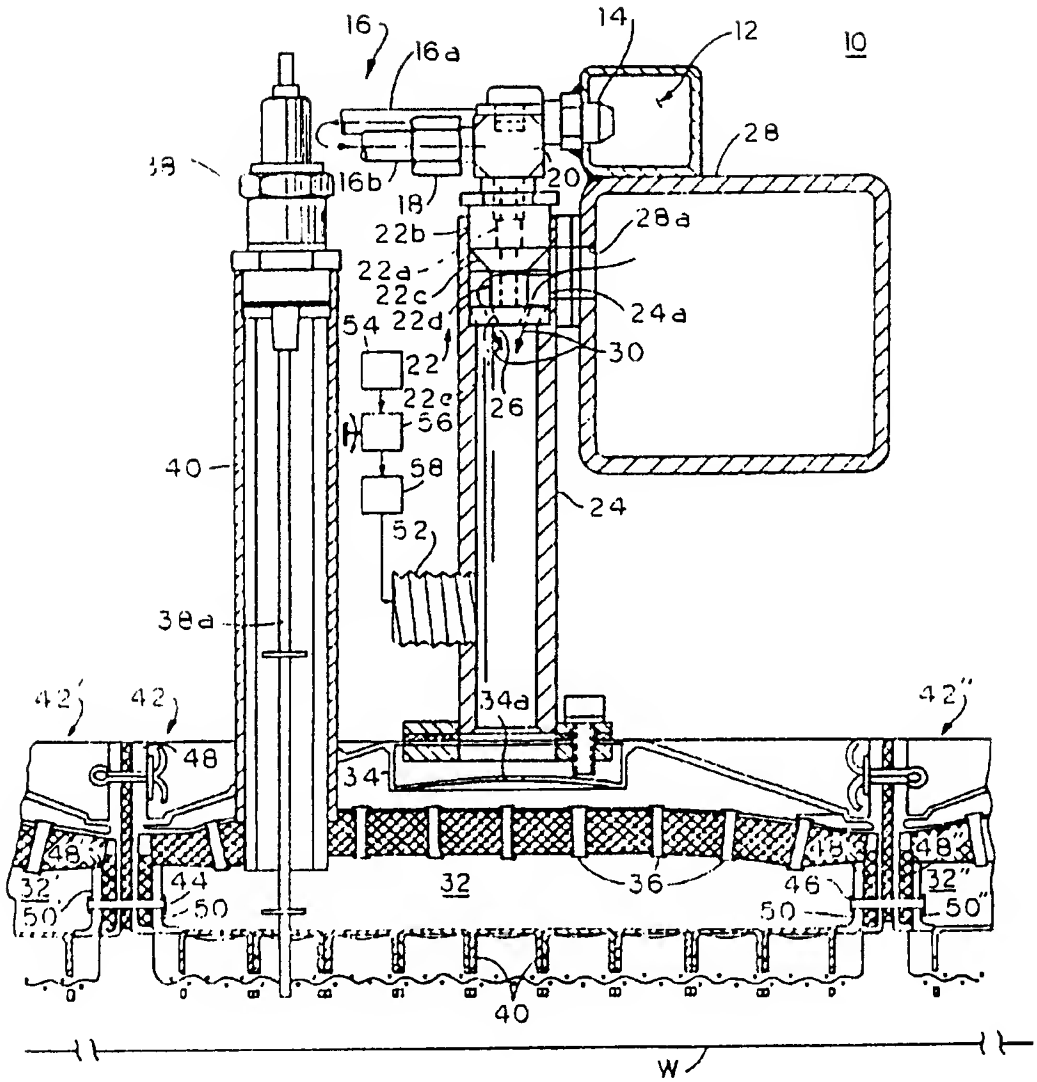
16
16a
14
12
10
28
38
16b
18
20
22b
28a
22a
22c
24a
22d
54
30
22
22e
26
56
40
58
24
52
38a
42'
42
42"
34a
48
34
48
32'
44
32
36
46
48"
32"
50'
50
50
50"
40
W

FIG.1

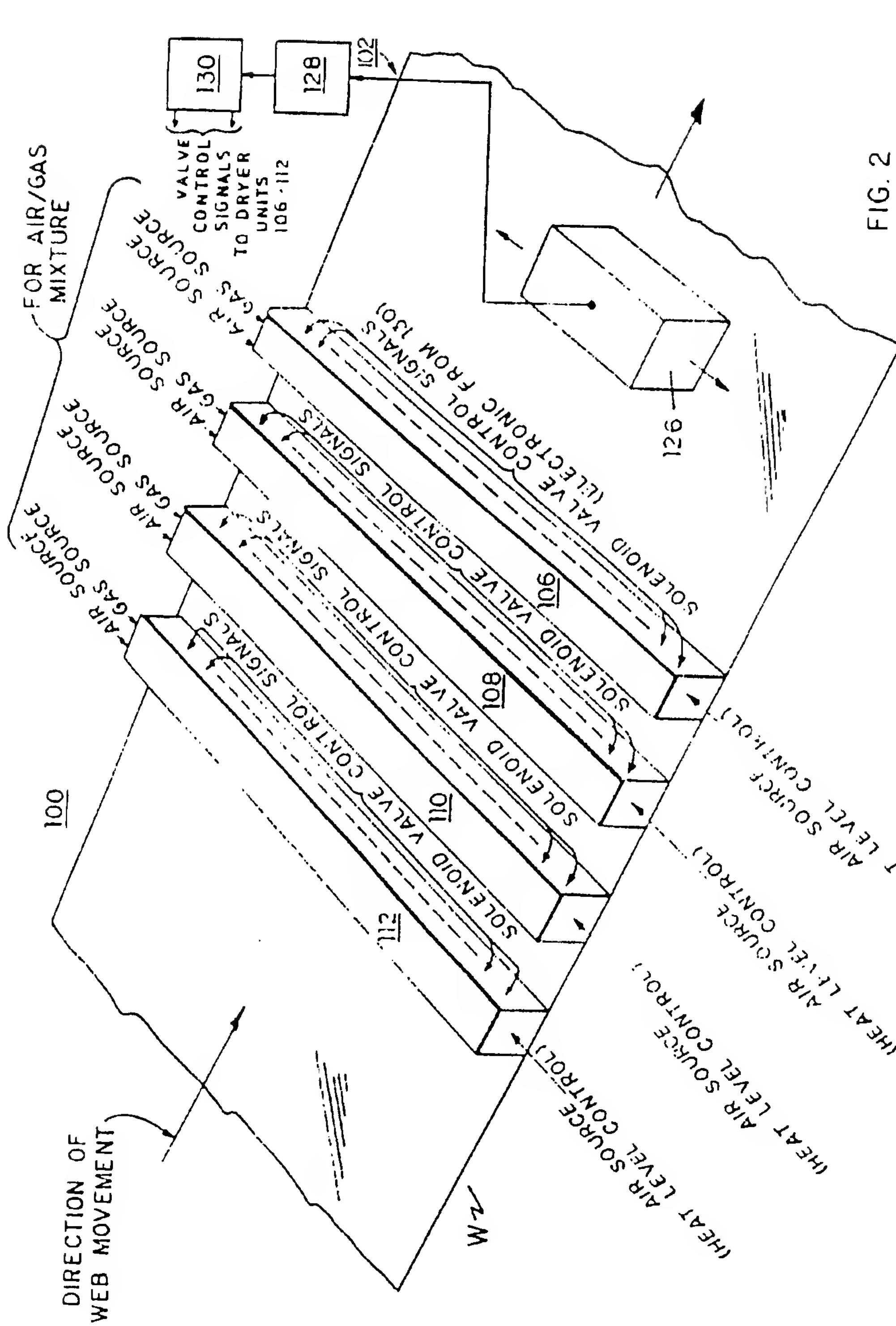
130
128
102
VALVE CONTROL SIGNALS TO DRYER UNITS 106-112
FOR AIR/GAS MIXTURE
GAS SOURCE
AIR SOURCE
SOLENOID VALVE CONTROL SIGNALS (ELECTRONIC FROM 130)
SOLENOID VALVE CONTROL SIGNALS
106
108
110
112
126
100
(HEAT AIR SOURCE LEVEL CONTROL)
DIRECTION OF WEB MOVEMENT
W

FIG. 2

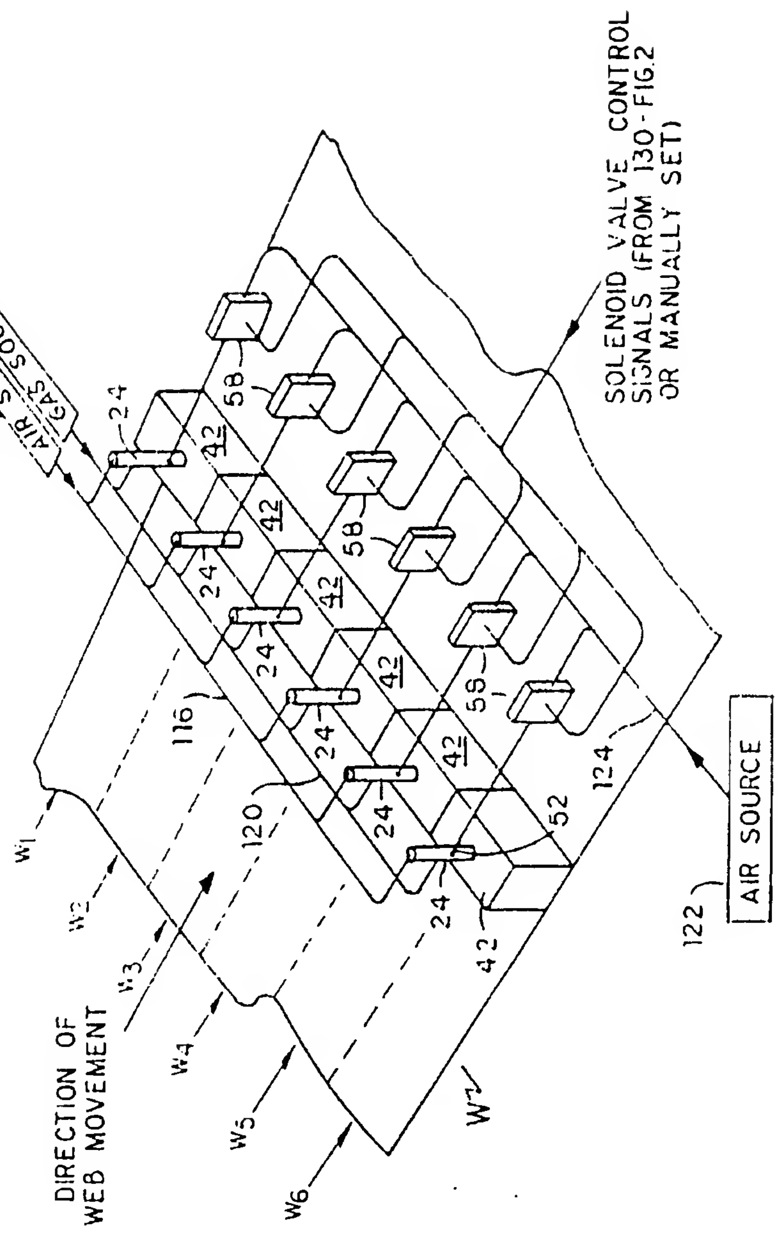
DIRECTION OF
WEB MOVEMENT
AIR SOURCE
AIR/GAS SOURCE
SOLENOID VALVE CONTROL
SIGNALS (FROM 130-FIG.2
OR MANUALLY SET)
AIR SOURCE
114
118
116
120
122
124
24
42
52
58

FIG.2a

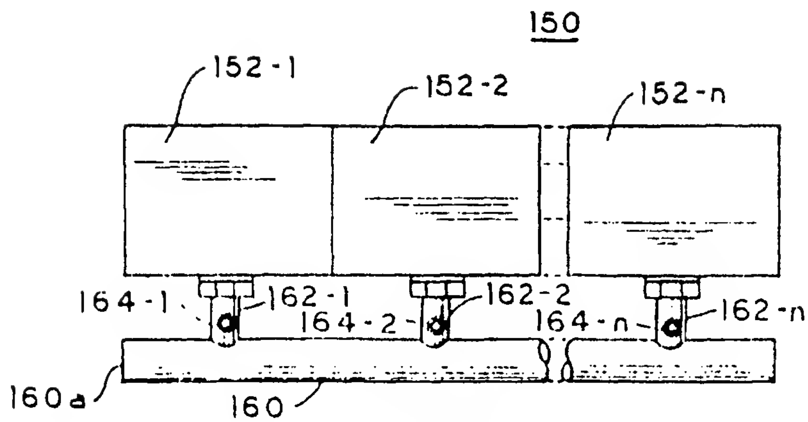

FIG. 3a

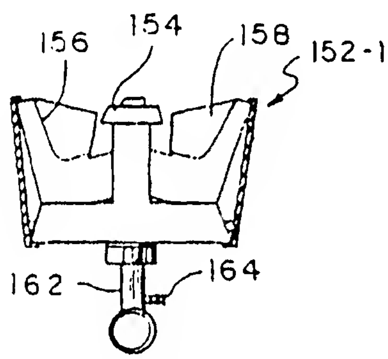

FIG. 3b

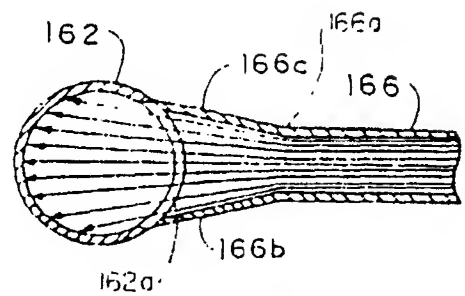

FIG. 4b

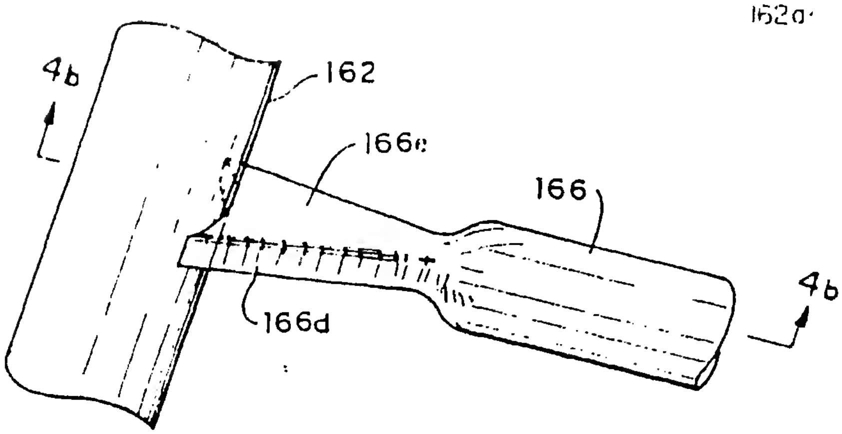

FIG. 4a

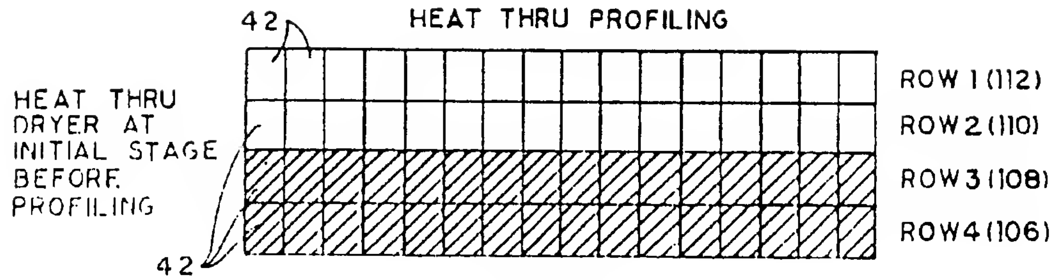

FIG. 5a

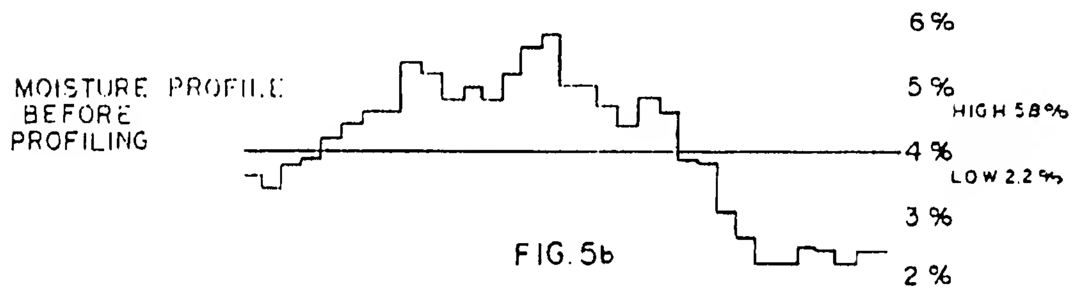

FIG. 5b

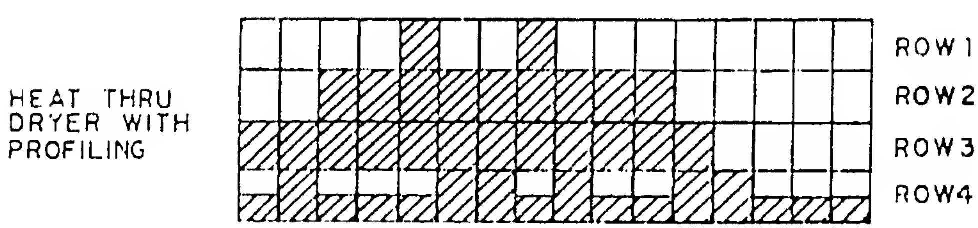

FIG. 5c

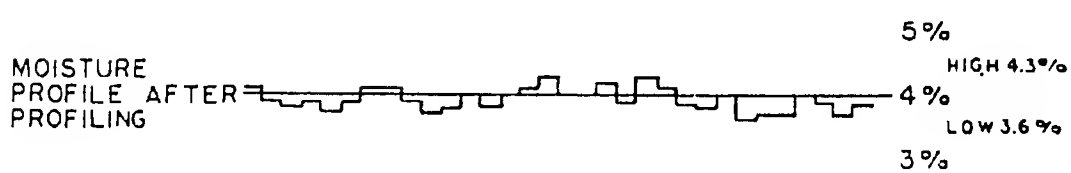

FIG. 5d

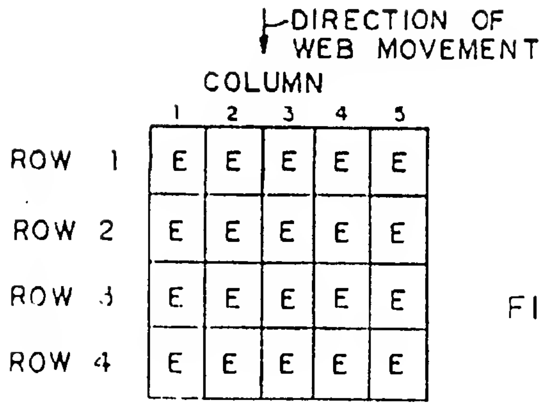

FIG.6

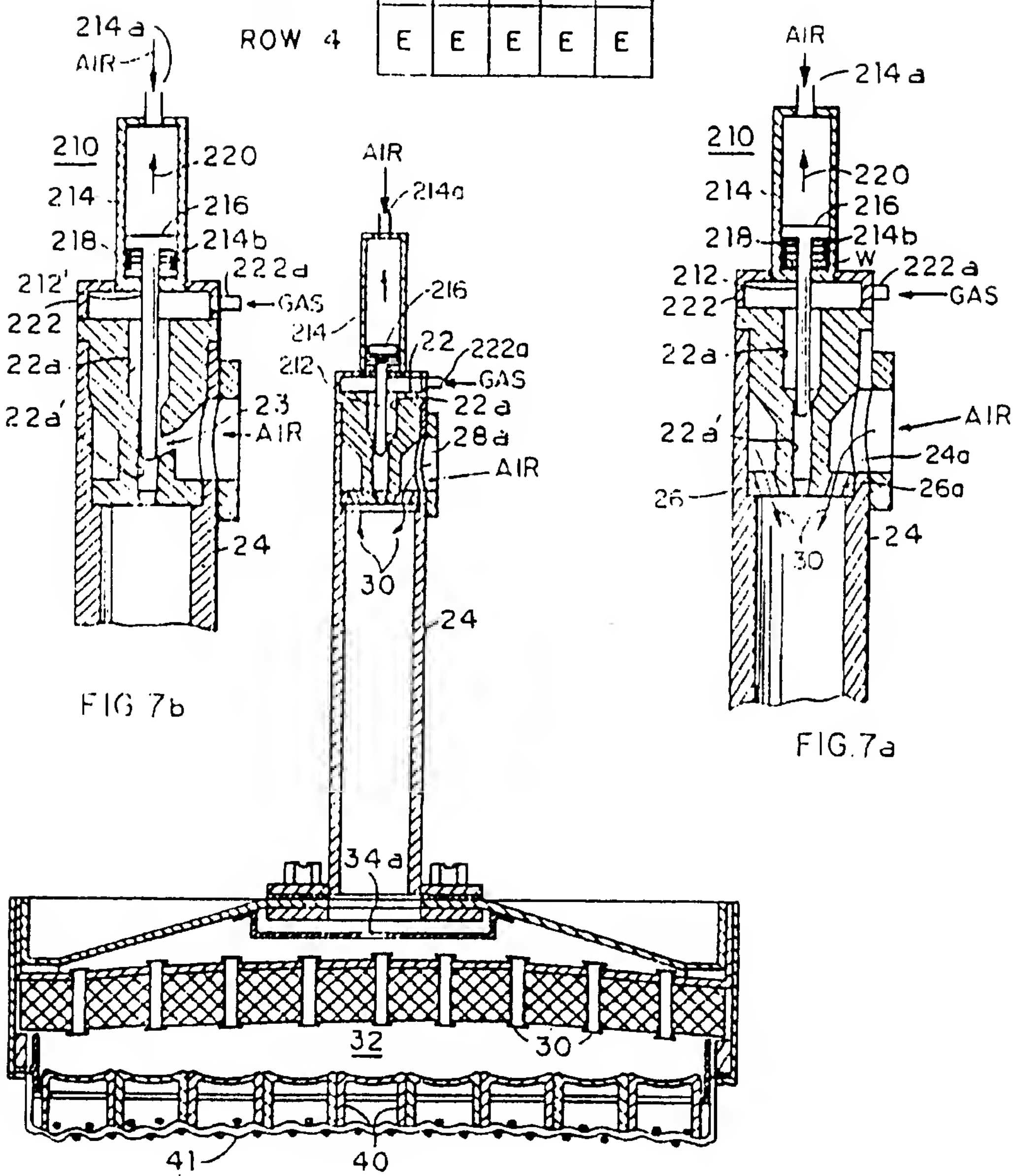

FIG 7b

FIG.7

FIG.7a